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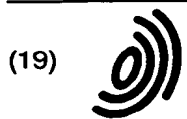
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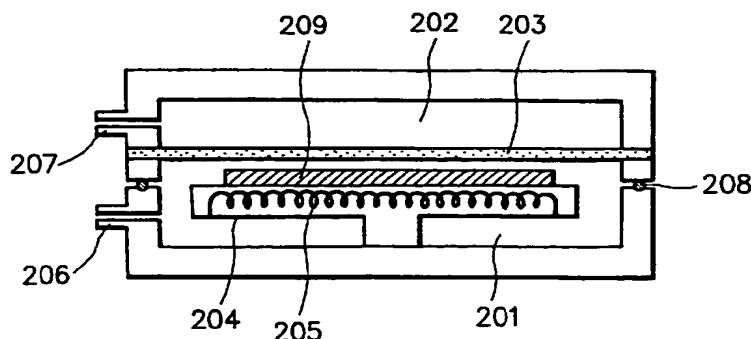
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(54) **A semiconductor device and a process for the production thereof**

(57) A semiconductor device having a semiconductor element, characterized in that said semiconductor device comprises a stacked body obtained by providing a laminate comprising said semiconductor element and a sealing resin which are interposed between a surface member and a back face member, vacuuming said laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting the laminate thus treated to thermo-

compression bonding at a vacuum degree of 5 Torr or less, and cooling the laminate having subjected to said thermocompression bonding to engage in contact bonding. And a process for the production of a semiconductor device. The semiconductor device is free of the generation of air bubble therein.

FIG. 2



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Descripti n

BACKGROUND OF THE INVENTION5 Field of the Invention

The present invention relates to an improved, highly reliable semiconductor device and a process for the production of said semiconductor device. More particularly, the present invention relates to an improved, highly reliable semiconductor device having a photoelectric conversion element sealed therein, specifically, an improved, highly reliable solar cell module having a sealing resin and a process for the production of said semiconductor device or solar cell module.

Related Background Art

15 In recent years, the societal consciousness for the problems relating to the environment and energy has been increasing all over the world. Particularly, heating of the earth because of the so-called greenhouse effect due to an increase of atmospheric CO₂ has been predicted to cause a serious problem. In view of this, there is an increased demand for a means of power generation capable of providing clean energy without causing CO₂ buildup.

Now, public attention has been focused on solar cells in order to meet such demand, because they can supply electric power without causing such a problem as above mentioned and are expected to be a future power generation source, and they are safe and easy to handle.

In order to use such a solar cell as a power generation source, it is usually designed into a module in a desired configuration which can be used as the power generation source.

In FIG. 1, there is shown an example of such solar cell module.

FIG. 1 is a schematic cross-sectional view of the solar cell module. In FIG. 1, reference numeral 101 indicates a photovoltaic element (or a photoelectric conversion element), reference numeral 102 a sealing resin (that is, a filler resin), reference numeral 103 a transparent surface protective member, and reference numeral 104 a back face protective member.

As the surface protective member 103, a glass member most often has been using.

Now, in recent years, public attention has been focused on solar cell modules having a so-called thin film solar cell represented by an amorphous silicon solar cell in which no glass member is used because they have various advantages such that they are light and excel in shock resistance and flexibility and they can be produced at a low production cost.

In these solar cell modules, the surface protective member 103 to cover the light incident side of the photovoltaic element 101 usually comprises a transparent film excelling in weatherability such as fluororesin film. The back face protective member 104 to cover the rear side of the photovoltaic element 101 usually comprises a resin film having an excellent insulating property such as nylon film, polyester film, or the like. In the case where the back face protective member 104 is required to have moisture resistance and weatherability in addition to the insulating property, it usually comprises an aluminium foil sandwiched with TEDLAR (trademark name).

The sealing resin 102 serves as an adhesive between the photovoltaic elements 101 and the surface protective member 103 and also as an adhesive between the photovoltaic element and the back face protective member 104. In addition to this, the sealing resin 102 also serves as a filler for filling the irregularities at the surface of the photovoltaic element 101 and for preventing the photovoltaic element from being externally damaged and from suffering from external shocks. The sealing resin 102 is usually constituted by a transparent thermoplastic resin such as polyvinyl butyral resin (PVB) or ethylene-vinyl acetate copolymer (EVA). Of these thermoplastic resins, EVA has been widely using because the use thereof as the sealing resin 102 is advantageous in that it is inexpensive and easy to handle, its heat resistance can be improved by way of crosslinking, and it is highly durable against the use in outdoors over a long period of time.

SUMMARY OF THE INVENTION

50 The production of a semiconductor device (that is, a solar cell module) having the above described configuration shown in FIG. 1 using EVA as the sealing resin 102 can be conducted in a manner of providing a stacked body comprising EVA as the sealing resin 102 and a photovoltaic element 102 which are interposed between a surface protective member 103 and a back face protective member 104 and subjecting the stacked body to thermocompression treatment using a laminater of a double vacuum chamber system (hereinafter referred to as double vacuum chambered laminater).

FIG. 2 is a schematic diagram illustrating an example of such double vacuum chambered laminater. In FIG. 2, reference numeral 201 indicates a lower chamber, reference numeral 202 an upper chamber, and reference numeral 203 a flexible member comprising a silicone rubber sheet which is hermetically provided between the lower chamber 201

and the upper chamber 202 so as to isolate one from the other. The lower chamber 201 contains a mounting table 204 made of a metal installed therein. The mounting table 204 is provided with an electric heater 205 installed therein. The lower chamber 201 is provided with an exhaust pipe 206 which is connected to a vacuum pump (not shown). The upper chamber 202 is provided with an exhaust pipe 207 which is connected to a vacuum pump (not shown). Reference numeral 208 indicates an O-ring disposed between the lower chamber 201 and the upper chamber 202. Reference numeral 209 indicates an object to be treated which is positioned on the mounting table 204. The mounting table 204 is also provided with a cooling system (not shown) through which a cooling medium such as cooling water is circulated in order to cool the object 209.

Description will be made of a manner of treating the above described stacked body using the laminater shown in FIG. 2 to produce a solar cell module while using a crosslinking type EVA as the sealing resin 102.

First, the stacked body as the object 209 to be treated is positioned on the mounting table 204 of the lower chamber 201. Thereafter, the inside of each of the lower chamber 201 and the upper chamber 202 is exhausted to a predetermined vacuum degree through the exhaust pipes 206 and 207 by operating the vacuum pump (not shown). Successively, the stacked body 209 is heated to a predetermined temperature at which the EVA as the sealing resin 102 can be fused without being crosslinked, by means of the electric heater 204. Then, while continuing the evacuation of the lower chamber 201, only the pressure of the inside of the upper chamber 202 is returned to an atmospheric pressure, wherein the flexible member 203 (the silicone rubber sheet) is sagged toward the lower chamber 201 side to compress the stacked body. Thereafter, the stacked body 209 is heated to and maintained at a predetermined temperature at which the EVA as the sealing resin 102 can be crosslinked to crosslink the EVA by means of the electric heater 204. The stacked body 209 thus treated is cooled to a predetermined temperature by means of the cooling system (not shown), and it is taken out of the laminater. By this, there can be obtained a solar cell module.

A semiconductor device (that is, a solar cell module) having the above described configuration shown in FIG. 1 using a crosslinking type EVA as the sealing resin 102 can be also produced using a laminater of a single vacuum chamber system (hereinafter referred to as single vacuum chambered laminater).

FIG. 3 is a schematic diagram illustrating an example of such single vacuum chambered laminater. The laminater shown in FIG. 3 comprises a mounting table 301 made of a metal which is provided with an exhaust system 304 which is connected to a vacuum pump (not shown). The mounting table 301 is provided with an electric heater 303 installed therein. Reference numeral 302 indicates a flexible member comprising a silicone rubber sheet which is disposed above the mounting table 301 such that a space is established between the surface of the mounting table 301 and the flexible member 302 as shown in FIG. 3. Reference numeral 305 indicates an O-ring which hermetically seals between the mounting table 301 and the flexible member 302. Reference numeral 306 indicates an object to be treated which is positioned on the surface of the mounting table 301 and within said space. The exhaust system 304 has a plurality of openings open into the above described space. The laminater shown in FIG. 3 is also provided with a cooling system such as a fan (not shown) which can supply a cooling medium such as air to cool the object 306.

Description will be made of a manner of producing a solar cell module using the laminater shown in FIG. 3.

First, there is provided a stacked body for a solar cell module, comprising a crosslinking type EVA as the sealing resin 102 and a photovoltaic element 102 which are interposed between a surface protective member 103 and a back face protective member 104.

The stacked body as the object 306 to be treated is positioned on the surface of the mounting table 301, and a silicone rubber sheet as the flexible member 302 is superposed over the stacked body 306 on the mounting table 301 while hermetically sealing between the mounting table 301 and the flexible member 302 by means of the O-ring 305 as shown in FIG. 3. Then, the inside of the space containing the stacked body 306 between the flexible member 302 and the mounting table 301 is exhausted to a predetermined vacuum degree through the openings of the exhaust system 304 by operating the vacuum pump (not shown) to sag the flexible member 302 toward the mounting table 301 side whereby compressing the stacked body 306. Then, the stacked body 306 is heated to and maintained at a predetermined temperature at which the EVA of the stacked body can be crosslinked by means of the electric heater 303, whereby the EVA of the stacked body is crosslinked. The stacked body thus treated is cooled to a predetermined temperature by means of the cooling system (not shown), and it is taken out from the laminater. By this, there can be obtained a solar cell module.

Now, in the manner using the single vacuum chambered laminater, being different from the manner using the double vacuum chambered laminater, the stacked body is compressed at the same of conducting the exhaustion, wherein the air present in the gaps of the stacked body is difficult to sufficiently release to the outside and therefore, there is a tendency that the module obtained after the lamination treatment is accompanied by residual air bubbles and it is defective in terms of exterior appearance.

In order to prevent the occurrence of this problem in the manner using the single vacuum chambered laminater, it is considered to insert a nonwoven fiber member into the stacked body.

FIG. 4 is a schematic explanatory view illustrating an example of the constitution of such stacked body having a nonwoven fiber member inserted therein. In FIG. 4, reference numeral 400 indicates a stacked body for a semiconductor device (a solar cell module), reference numeral 401 a photovoltaic element (or a semiconductor element), reference

numeral 402 a nonwoven fiber member, reference numeral 403 a sealing resin (for example, EVA), reference numeral 404 a surface protective member, and reference numeral 405 a back face protective member.

In this embodiment, the nonwoven fiber member 402 comprises a nonwoven glass fiber member for the purpose of facilitating the release of the air present in the gaps of the stacked body. In this case, the air present in the stacked body can be released to the outside through the gaps of the nonwoven glass fiber member during the exhaustion process. By this, the situation of entailing the foregoing problem of causing the generation of residual air bubbles in the stacked body in the manner using the single vacuum chambered laminater can be improved. Further, in this case, the glass fiber member has a refractive index which is quite similar to that of EVA, and therefore, when the glass fiber member should be disposed on the light incident side of the photovoltaic element, a substantial loss in the quantity of light impinging due to light scattering is not occurred. In addition to this, the glass fiber member excels in weatherability. In this respect, the use of the glass fiber member is advantageous.

However, any of the manner using the single vacuum chambered laminater and the manner using the double vacuum chambered laminater is liable to entail a problem in that the resulting module is accompanied by residual air bubbles therein due to insufficient exhaustion. This problem is very likely to occur in the manner using the single vacuum chambered laminater. Particularly, even if the glass fiber member should be used as above describe, in the case where the stacked body is of a large size, the generation of residual air bubbles is liable to occur in the stacked body wherein the stacked body obtained after the lamination treatment is defective in terms of exterior appearance. This situation leads to causing a reduction in the yield of a semiconductor device (a solar cell module) produced. As for the reason for this, it is considered that since the stacked body has a large size, the stacked body unavoidably has an increased exhaustion resistance in terms of exhausting the air present in the gaps of the stacked body and therefore, the air present in the stacked body cannot be completely released to the outside.

Now, as for a solar cell module having a surface cover comprising a fluoro resin film under which a EVA containing a crosslinking agent as the sealing resin for the photovoltaic element is situated, when the solar cell module is subjected to the temperature cycle test, temperature and humidity cycle test, and outdoor exposure test in order to evaluate its reliability, there is a tendency that the fluoro resin film is peeled. As for the fluoro resin film, it is usually designed to have a corona-discharged surface to be contacted with the sealing resin in order to attain an improvement in the adhesion of the fluoro resin film with the sealing resin. However, even in this case, the fluoro resin film is still sometimes peeled in the above described tests because its adhesion with the sealing resin is not sufficient enough. As one of the causes of entailing this problem, there is considered the vacuum degree employed in the lamination process. In more detail, there are considered such reasons as will be described in the following. That is, as a mechanism of bonding the fluoro resin film with the EVA as the sealing resin, there is considered the generation of a covalent bonding due to a radical provided by the crosslinking agent contained in the EVA between the corona-discharged surface of the fluoro resin film and the EVA as the sealing resin. In the case where the vacuum degree employed in the lamination process is low, it is considered that the generation of said radical is prevented by oxygen remained in the system of the lamination process and because of this, there cannot be attained a sufficient adhesion between the EVA as the sealing resin and the fluoro resin film. In this case, it is also considered that the EVA as the sealing resin itself is not sufficiently crosslinked and because of this, the EVA is liable to soften under use condition with a high temperature, resulting in causing a separation between the sealing resin and the fluoro resin film.

Accordingly, an object of the present invention is to provide a semiconductor device including a solar cell module provided with an improved surface covering material which is hardly peeled even upon repeated use under environmental conditions having changes in temperature and humidity in outdoors.

Another object of the present invention is to provide a process for the production of a semiconductor device including a solar cell module having an improved covering material with no residual air bubble and which has an excellent exterior appearance at a high yield.

A further object of the present invention is to provide a semiconductor device which comprises a stacked body obtained by providing a laminate comprising a semiconductor element and a sealing resin which are interposed between a surface member and a back face member, vacuuming said laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting the laminate thus treated to thermocompression bonding under condition with a vacuum degree of 5 Torr or less, and cooling the laminate having subjected to said thermocompression bonding to engage in contact bonding.

A further object of the present invention is to provide a process for the production of a semiconductor device by subjecting a stacked body comprising a semiconductor element and a sealing resin which are interposed between a surface member and a back face member to thermocompression bonding while conducting exhaustion, characterized in that said process comprises: (a) a vacuuming step of vacuuming said stacked body at a vacuum degree of 5 Torr or less for 5 to 40 minutes, (b) a thermocompression bonding step of subjecting the stacked body vacuum-treated in said step (a) to thermocompression bonding under condition of maintaining the condition in said step (a) with the vacuum degree of 5 Torr or less, and (c) a cooling step of cooling the stacked body treated in said step (b) to engage in contact bonding under condition of maintaining the condition in said step (a) with the vacuum degree of 5 Torr or less.

A feature of the process for the production of a semiconductor device in the present invention lies in that under the

condition with a vacuum degree of 5 Torr or less, a stacked body comprising a semiconductor element and a sealing resin which are interposed between a surface member and a back face member is vacuumed for 5 to 40 minutes, then the stacked body thus vacuum-treated is subjected to thermocompression bonding, and successively, the stacked body having subjected to said thermocompression bonding is cooled to engage in contact bonding.

According to the process for the production of a semiconductor device in the present invention, there are provided such significant advantages as will be described below.

(1) Because the stacked body for a semiconductor device is sufficiently vacuumed, the air present in the gaps of the stacked body is entirely released to the outside and hence, the stacked body treated is free of a residual air bubble therein.

(2) And, in the case where the sealing resin is crosslinked by means of an organic peroxide, the generation of a covalent bonding between the surface member and the sealing resin and the crosslinking of the sealing resin itself are desirably occurred without being hindered by oxygen. Because of this, there is attained an excellent adhesion between the surface member and the sealing resin, and there is not occurred a problem in that the sealing resin is softened to cause a separation of the surface member, even upon repeated use under environmental condition with a high temperature.

In the present invention, the stacked body is desired to have a nonwoven glass fiber member, a nonwoven organic resin fiber member, or both of these fibers inserted therein.

Further, it is desired that the sealing resin disposed between the photovoltaic element and the surface member is constituted by EVA (ethylene-vinyl acetate copolymer), and the surface member is constituted by a transparent film composed of a fluorine-containing polymer.

The EVA as the sealing resin is desired to be crosslinked by an organic peroxide.

The fluorine-containing polymer by which the transparent film as the surface member is desired to be ETFE (ethylene-tetrafluoroethylene copolymer).

In addition, the fluorine-containing polymer film is desired to be designed such that it has a corona-discharged surface to be contacted with the sealing resin.

Further, in the process for the production of a semiconductor in the present invention, the thermocompression bonding of the stacked body is desired to be conducted in a manner of supporting the stacked body between a plate as the mounting table and a compressing member (or a flexible member) comprising a silicone rubber sheet for example, vacuuming the space between the mounting table and the compressing member, and compressing the compressing member to the stacked body in the vacuuming step, thermocompression bonding step, and cooling step by means of the single vacuum chambered.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view illustrating a conventional solar cell module.

FIG. 2 is a schematic diagram illustrating a laminator of a double vacuum chamber system.

FIG. 3 is a schematic diagram illustrating a laminator of a single vacuum chamber system.

FIG. 4 is a schematic view illustrating the constitution of an example of a stacked body as a semiconductor device (or a solar cell module).

FIG 5 is a schematic cross-sectional view illustrating a semiconductor device (or a solar cell module).

FIG. 6(a) is a schematic cross-sectional view illustrating the constitution of an example of a photoelectric conversion element which can be used in the present invention.

FIG. 6(b) is a schematic plan view illustrating a light receiving face of the photoelectric conversion element shown in FIG. 6(a).

FIG. 7 (a) is a schematic explanatory view of a preparatory step for conducting vacuum lamination by means of a single vacuum chamber system.

FIG. 7(b) is a schematic diagram illustrating a laminator of a single vacuum chamber system.

FIG. 8 is a schematic view illustrating the constitution of another example of a stacked body as a semiconductor device (or a solar cell module).

FIG. 9 is a schematic view illustrating the constitution of a further example of a stacked body as a semiconductor device (or a solar cell module).

DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

The present invention is to attain the above described objects.

As above described, the present invention provides an improved, highly reliable semiconductor device and a production for the production of said semiconductor device.

A typical embodiment of the semiconductor device according to the present invention comprises a stacked body obtained by providing a laminate comprising a semiconductor element such as a photoelectric conversion element including a photovoltaic element and a sealing resin which are interposed between a surface member (or a surface protective member) and a back face member (or a back face protective member), vacuuming said laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting the laminate thus treated to thermocompression bonding under condition with a vacuum degree of 5 Torr or less, and cooling the laminate having subjected to said thermocompression bonding to engage in contact bonding.

A typical embodiment of the process for the production of a semiconductor device comprises (a) a vacuuming step of vacuuming a stacked body for a semiconductor device comprising a semiconductor element such as a photoelectric conversion element including a photovoltaic element and a sealing resin which are interposed between a surface member (or a surface protective member) and a back face member (or a back face protective member) at a vacuum degree of 5 Torr or less for 5 to 40 minutes, (b) a thermocompression bonding step of subjecting the stacked body vacuum-treated in said step (a) to thermocompression bonding under condition of maintaining the condition in said step (a) with the vacuum degree of 5 Torr or less, and (c) a cooling step of cooling the stacked body treated in said step (b) to engage in contact bonding under condition of maintaining the condition in said step (a) with the vacuum degree of 5 Torr or less.

In the following, description will be described of a solar cell module as a semiconductor device according to the present invention.

FIG. 5 is a schematic cross-sectional view illustrating the constitution of an example of a solar cell module as a semiconductor device according to the present invention.

In FIG. 5, reference numeral 501 indicates a photovoltaic element as a semiconductor element, reference numeral 502 a transparent or substantially transparent sealing resin (this sealing resin will be hereinafter referred to as surface side sealing resin), reference numeral 503 a transparent or substantially transparent surface member which is positioned at the outermost surface (this member will be hereinafter referred to as surface protective member), reference numeral 504 a sealing resin on the rear side of the photovoltaic element 501 (this sealing resin will be hereinafter referred to as backside sealing resin), and reference numeral 505 a back face member (this member will be hereinafter referred to as back face protective member).

In the solar cell module shown in FIG. 5, light is impinged through the surface protective member 503 side, and the light impinged passes through the surface protective member 503 and surface side sealing resin 502 to arrive in the photovoltaic element 501.

A photoelectromotive force generated in the photovoltaic element 501 is outputted through outputting terminals (not shown).

The photovoltaic element 501 may comprises an appropriate photovoltaic element used in single crystal silicon solar cells, polycrystalline silicon solar cells, amorphous silicon solar cells, copper-indium-selenide solar cells, or compound semiconductor solar cells.

Herein, as an example of such photovoltaic element, description will be made of a photovoltaic element having a structure comprising a semiconductor active layer as a photoelectric conversion member and a transparent and conductive layer disposed in the named order on an electrically conductive substrate.

FIG. 6(a) is a schematic cross-sectional view illustrating the constitution of such photovoltaic element. FIG. 6(b) is a schematic plan view illustrating the light receiving face of the photovoltaic element shown in FIG. 6(a).

In FIGs. 6(a) and 6(b), reference numeral 601 indicates an electrically conductive substrate, reference numeral 602 a back reflecting layer, reference numeral 603 a semiconductor active layer, reference numeral 604 a transparent and conductive layer, reference numeral 605 a collecting electrode (or a grid electrode), reference numeral 606a a power outputting terminal on the positive side, reference numeral 606b a power outputting terminal on the negative side, reference numeral 607 an electrical connection means, and reference numeral 608 an electrical connection means.

The photovoltaic element shown in FIGs. 6(a) and 6(b) comprises the back reflecting layer 602, the semiconductor active layer 603, the transparent and conductive layer 604, and the collecting electrode 605 disposed in the named order on the electrically conductive substrate 601, wherein the outputting terminal 606a is electrically connected to the collecting electrode 605 by means of the electrical connection means 607 and it is extending from the correcting electrode while being insulated by means of an insulating member (not shown), and the outputting terminal 606b is electrically connected to the electrically conductive substrate 601 by means of the electrical connection means 608. In this configuration, the positive side power outputting terminal and the negative side power outputting terminal may be changed into a negative side power outputting terminal and a positive side power outputting terminal depending upon the constitution of the semiconductor active layer.

The electrically conductive substrate 601 serves not only as a substrate for the photovoltaic element but also as a lower electrode. As for the electrically conductive substrate 601, there is no particular restriction as long as it has an electrically conductive surface. Specifically, it may be an electrically conductive member composed of a metal such as Si, Ta, Mo, W, Al, Cu, Ti, or Fe, or an electrically conductive member composed of an alloy of these metals such as stainless steel, or the like. Besides these, the electrically conductive substrate 601 may comprise a carbon sheet or a Pb-plated steel sheet. Alternatively, the electrically conductive substrate 601 may be a film or sheet made of a synthetic

resin or a sheet made of a ceramic. In this case, the substrate is deposited with an electrically conductive film on the surface thereof.

The back reflecting layer 602 disposed on the electrically conductive substrate 601 may comprise a metal layer, a metal oxide layer, or a two-layered structure comprising a metal layer and a metal oxide layer. The metal layer may be composed of a metal such as Ti, Cr, Mo, W, Al, Ag, or Ni, or an alloy of these metals. The metal oxide layer may comprise a metal oxide such as ZnO, TiO₂, SnO₂, or the like.

The back reflecting layer 602 is desired to have a roughened surface in order to make incident light to be effectively utilized.

The back reflecting layer 602 may be properly formed by a conventional film-forming technique such as resistant heating evaporation, electron beam evaporation, or sputtering.

The semiconductor active layer 603 functions to conduct photoelectric conversion. The semiconductor active layer may be composed of a non-single crystal silicon semiconductor material such as an amorphous silicon semiconductor material or polycrystalline silicon semiconductor material, or a compound semiconductor material. In any case, the semiconductor active layer comprised of any of these semiconductor materials may be of a stacked structure with a pin junction, a pn junction or a shottky type junction. Specific examples of the compound semiconductor material are CuInSe₂, CuInS₂, GaAs, CdS/Cu₂S, CdS/CdTe, CdS/InP, CdTe/Cu₂Te, and the like.

The semiconductor active layer 603 comprised of any of the above mentioned semiconductor materials may be properly formed by a conventional film-forming technique. For instance, the non-single crystal silicon semiconductor active layer may be formed by a conventional chemical vapor phase growing technique such as plasma CVD or light-induced CVD using proper film-forming raw material gas capable of imparting silicon atoms such as silane gas or a conventional physical vapor phase growing technique such as sputtering using a Si-target. The semiconductor active layer composed of a polycrystalline silicon semiconductor material may be formed by a conventional polycrystalline silicon film-forming manner of providing a fused silicon material and subjecting the fused silicon material to film-making processing or another conventional polycrystalline silicon film-forming manner of subjecting an amorphous silicon material to heat treatment.

The semiconductor active layer 603 composed of any of the above mentioned compound semiconductor materials may be properly formed by a conventional ion plating, ion beam deposition, vacuum evaporation, sputtering, or electrolytic technique in which a precipitate is caused by way of electrolysis of a desired electrolyte.

The transparent and conductive layer 604 functions as an upper electrode. The transparent and conductive layer may comprise In₂O₃, SnO₂, In₂O₃-SnO₂ (ITO), ZnO, TiO₂, or Cd₂SnO₄. Besides these, it may comprise a crystalline semiconductor layer doped with an appropriate impurity with a high concentration.

The transparent and conductive layer 604 constituted by any of the above mentioned materials may be properly formed by a conventional resistant heating evaporation, electron beam evaporation, sputtering, spraying, or CVD.

The above described impurity-doped crystalline semiconductor layer as the transparent and conductive layer 604 may be properly formed by a conventional impurity-diffusion film-forming method.

For the purpose of effectively collecting an electric current generated by virtue of a photoelectromotive force, the collecting electrode (or the grid electrode) 605 is may be disposed on the transparent and conductive layer 604. The collecting electrode 605 is may be in the form of a stripe shape or comb shape.

The collecting electrode 605 may comprise a metal such as Ti, Cr, Mo, W, Al, Ag, Ni, Cu, or Sn, or an alloy of these metals. Alternatively, the collecting electrode 605 may be formed of an electrically conductive paste or an electrically conductive resin. The electrically conductive paste can include electrically conductive pastes comprising powdery Ag, Au, Cu, Ni, or carbon dispersed in an appropriate binder resin. The binder resin herein can include polyester, epoxy resin, acrylic resin, alkyd resin, polyvinyl acetate, rubber, urethane resin, and phenol resin.

The collecting electrode 605 may be properly formed by means of sputtering using a mask pattern, resistant heating evaporation, or CVD. It may be also properly formed by a manner of depositing a metal film over the entire surface and subjecting the metal film to etching treatment to form a desired pattern, a manner of directly forming a grid electrode pattern by means of light-induced CVD, or a manner of forming a negative pattern corresponding to a grid electrode pattern and subjecting the resultant to plating treatment.

The formation of the collecting electrode 605 using any of the above described electrically conductive pastes may be conducted in a manner of subjecting the electrically conductive paste to screen printing or a manner of fixing a metal wire to the screen-printed electrically conductive paste, if necessary, using a solder.

The outputting terminals 606a and 606b serve to output an electromotive force. The outputting terminal 606a is electrically connected to the collecting electrode 605 by means of the electrical connection means 607. The electrical connection means 607 may comprise an electrically conductive layer formed by using a metal body and an electrically conductive paste or a solder. The outputting terminal 606b is electrically connected to the electrically conductive substrate by means of the electrical connection means 608. The electrical connection means 608 may comprises an electrical connection region formed by spot welding or soldering an appropriate metal body such as copper tab.

In general, there are provided a plurality of photovoltaic elements having the above constitution, and they are integrated in series connection or in parallel connection depending upon a desired voltage or electric current. It is possible

to dispose the integrated body on an insulating member such that a desired voltage or electric current can be obtained.

Description will be made of the surface side sealing resin 502 used in the present invention.

The surface side sealing resin 502 serves to coat the irregularities at the surface of the photovoltaic element 501 (the semiconductor element) with a given resin, to prevent the photovoltaic element from being influenced by external factors such as temperature changes and/or humidity changes in the external environment, externally applied impacts, or the like and to attain a sufficient adhesion between the photovoltaic element and the surface protective member 503. Thus, the surface side sealing resin is required to excel in weatherability, adhesion, packing property, heat resistance, cold resistance, and impact resistance. In order for the surface side sealing resin 502 to meet these requirements, the surface side sealing resin is comprised of a resin selected from the group consisting of polyolefinic resins, butyral resins, urethane resins, silicone resins, and fluororesins. Specific examples are EVA (ethylene-vinyl acetate copolymer), EMA (ethylene-methyl acrylate copolymer), EEA (ethylene-ethyl acrylate copolymer), and polyvinyl butyral resin. Of these resins, EVA is the most desirable because it exhibits well-balanced physical properties suitable for a solar cell when used as the surface side sealing resin.

Any of the above mentioned resins usable as the surface side sealing resin 502 is low in heat deformation temperature and is liable to readily deform or creep at a high temperature. Because of this, any of these resins is desired to be crosslinked with an appropriate crosslinking agent so that it has an increased heat resistance. As the crosslinking agent, there can be mentioned organic peroxides.

The crosslinking of the resin used as the surface side sealing resin 502 using an organic peroxide as the crosslinking agent is performed by way of incorporating hydrogen atoms or halogen atoms in the resin by virtue of free radicals generated from the organic peroxide to form C-C bonds.

In order to make the organic peroxide to generate such free radicals upon crosslinking the resin used as the surface side sealing resin, the organic peroxide is desired to be activated by means of a thermal decomposition process, redox decomposition process, or ion decomposition process. Of these processes, the thermal decomposition process is the most appropriate.

The organic peroxide usable as the crosslinking agent in the present invention can include hydroperoxide, dialkyl (diallyl) peroxide, diacyl peroxide, peroxyketal, peroxyester, peroxy carbonate, and ketone peroxide.

The amount of such organic peroxide as the crosslinking agent to be added to the resin as the surface side sealing resin is preferably in the range of from 0.5 to 5 parts by weight versus 100 parts by weight of the resin as the surface side sealing resin.

The organic peroxide as the crosslinking agent may be used together with the resin as the surface side sealing resin upon thermocompression bonding the resin as the surface side sealing resin under vacuum condition and while heating under compression condition.

Conditions of the temperature and the period of time for the thermocompression bonding treatment in this case may be determined depending upon the thermodecomposition temperature property of the organic peroxide used.

However, in general, these conditions are determined to be such that 90% or more or preferably 95% or more of the organic peroxide in the resin as the surface side sealing resin is thermally decomposed, whereby the resin as the surface side sealing resin is subjected to thermocompression bonding to the photovoltaic element and to the surface protective member while being crosslinked.

The degree of crosslinking of the resin as the surface side sealing resin can be examined by observing the gel content of the resin as the surface side sealing resin. In order to prevent the resin as the surface side sealing resin from being deformed, it is desired for the resin to be crosslinked such that the gel content is 70 wt.% or more.

In order to efficiently crosslink the resin as the surface side sealing resin, it is desired to use a crosslinking enhancer such as triaryl cyanurate (TAIC) in addition to the organic peroxide as the crosslinking agent. In this case, the amount of the crosslinking enhancer to be added is preferably in the range of from 1 to 5 parts by weight versus 100 parts by weight of the resin as the surface side sealing resin.

The surface side sealing resin 502 comprised of essentially of the above described resin material excels in weatherability. However, in order to attain a further improved weatherability for the surface side sealing resin and also in order to effectively protect a layer situated thereunder, it is possible for the surface side sealing resin to contain an appropriate UV absorber. As such UV absorber, there can be used commercially available chemical compounds usable as a UV absorber. Specific examples are organic compounds such as salicylic acid series compounds, benzophenone series compounds, benzotriazole series compounds, and cyanoacrylate series compounds. In a preferred embodiment, it is desired to use an UV absorber having a low volatility in view of use environment for a solar cell module.

The amount of the UV absorber to be added is preferably in the range of from 0.1 to 1.0 wt.% versus the amount of the resin as the surface sealing resin.

Further, in order to improve the resistance to photo-induced degradation of the surface side sealing resin, it is possible for the resin as the surface side sealing resin to contain an appropriate photo stabilizer in addition to the above described UV absorber. Such photo stabilizer can include hindered amine series photo stabilizers. Although the hindered amine series photo stabilizer does not absorb ultraviolet rays as the foregoing UV absorber does, a pronounced advantage is provided by using the hindered amine series light stabilizer in combination with the UV absorber.

The amount of the hindered amine series photo stabilizer to be added is preferably in the range of from 0.05 to 1.0 wt.% versus the amount of the resin as the surface side sealing resin.

Besides the above described hindered amine series photo stabilizers, there are known other photo stabilizers, but those photo stabilizers are not desirable to use in the resin as the surface side sealing resin because they are mostly colored and they are therefore liable to impart a negative influence of reducing the photoelectric conversion efficiency of a photovoltaic element particularly in the case of a solar cell module.

Further in addition, in order to attain a further improved heat resistance and thermally processing property for the resin as the surface side sealing resin, it is possible for the resin as the surface side sealing resin to contain an appropriate antioxidant. Such antioxidant can include monophenol series antioxidant, bisphenol series antioxidant, high-molecular phenol series antioxidant, sulphur series antioxidant, and phosphorous series antioxidant.

The amount of the antioxidant to be added is preferably in the range of from 0.05 to 1.0 wt.% versus the amount of the resin as the surface side sealing resin.

Now, in the case where the solar cell module is used under severe environmental conditions, it is desired to have excellent adhesion between the surface side sealing resin and the photovoltaic element and also between the surface side sealing resin and the surface protective member.

In order for the surface side sealing resin to attain such adhesion, it is effective to incorporate an appropriate silane coupling agent or an appropriate organic titanate compound into the resin as the surface side sealing resin. The amount of such silane coupling agent or organic titanate compound to be added is preferably in the range of from 0.1 to 3 parts by weight or more preferably in the range of from 0.25 to 1 part by weight, versus 100 parts by weight of the resin as the surface side sealing resin.

Now, in order to prevent a decrease in the quantity of incident light to be arriving in the photovoltaic element, the surface side sealing resin is desired to be substantially transparent. Specifically, it is desired for the surface side sealing resin to have a transmittance of preferably 80% or more or more preferably 90% or more in a visible light wavelength region of 400 nm to 800 nm. Further, in order to facilitate external light to be readily impinged into the photovoltaic element, the surface side sealing resin is desired to be made such that it has a refractive index of preferably 1.1 to 2.0 or more preferably 1.1 to 1.6 at a temperature of 25 °C.

There are commercially available EVA sheets containing the foregoing additives which are usable in a solar cell module. Specific examples are SOLAR EVA (trademark name, produced by High Sheet Kohgyo Kabushiki Kaisha), EVASAFE WG series EVA sheets (trademark name, produced by Bridgestone Kabushiki Kaisha), and PHOTOCAP (trademark name, produced by Springbone Laboratories Company). By inserting any of these EVA sheets between the photovoltaic element and the surface protective member and conducting thermocompression bonding therefor, there can be readily obtained a solar cell module.

In the following, description will be made of the surface protective member 503.

The surface protective member 503 is positioned at the outermost surface of the solar cell module and because of this, it is required to excel in transparency, weatherability, water repellency, heat resistance, pollution resistance, and physical strength. In addition, in the case where the solar cell module is used under severe environmental conditions in outdoors, it is required for the surface protective member to ensure that the solar cell module is of sufficient durability upon repeated use over a long period of time.

Therefore, the surface protective member 503 comprises a member which satisfies all these conditions. Such member can include white tempered glass members, fluoro-resin films, and acrylic resin films. The white tempered glass member excels in transparency and impact resistance and is hardly broken and therefore, it has been widely using as the surface protective member for a solar cell module.

However, in recent years, there is an increased demand for a solar cell module to be light and excel in flexibility. In order to meet this demand, the surface protective member is desired to comprise a film composed of a highly transparent fluoro-resin which excels especially in weatherability and pollution resistance.

Specific examples of such highly transparent fluoro-resin are polyvinylidene fluoride resin (PVdF), polyvinyl fluoride resin (PVF), ethylene-tetrafluoroethylene copolymer (ETFE), and the like. Of these fluoro-resins, PVdF is the most excellent in terms of weatherability. In terms of weatherability and physical strength in combination, ETFE is the most excellent.

The surface protective member 503 is desired to be relatively thick in order to attain a sufficient physical strength therefor. However, the surface protective member having an excessive thickness is problematic in view of the production cost for a solar cell module obtained and also the quantity of light impinged therethrough. Therefore, the surface protective member is desired to have a thickness preferably in the range of from 20 to 200 μm or more preferably in the range of from 30 to 100 μm .

In order to attain a further improvement in the adhesion of the surface protective member 503 with the surface side sealing resin 502, a given surface of the surface protective member to be contacted with the surface side sealing resin is desired to be subjected to surface treatment. The surface treatment in this case can include corona discharging treatment, plasma treatment, ozone treatment, UV irradiation, electron beam irradiation, and flame treatment. Of these, the corona discharging treatment the most desirable because there can be attained the purpose at a high speed while

using a relatively simple apparatus.

In the following, description will be made of the back face protective member 505.

The back side protective member 505 is disposed for the purpose of electrically insulating the electrically conductive substrate of the photovoltaic element 501 from the outside. The back face protective member 505 is desired to be composed of a material capable of sufficiently electrically isolating the electrically conductive substrate of the photovoltaic element and which excels in durability, withstands a thermal expansion and thermal contraction, and excels in flexibility. Specific examples of such material are nylon, polyethylene terephthalate (PET), and the like.

In the following, description will be made of the backside sealing resin 504.

The backside sealing resin 504 serves to ensure the adhesion between the photovoltaic element 501 and the back face protective member 505. The backside sealing resin 504 is desired to comprise a material capable of sufficiently ensuring the adhesion between the electrically conductive substrate of the photovoltaic element 501 and the back face protective member 505 and which excels in durability, withstands a thermal expansion and thermal contraction, and excels in flexibility. Specific examples of such material are hot-melt materials such as EVA (ethylene-vinyl acetate copolymer) and polyvinyl butyral, and epoxy adhesives. Besides these, double-coated tapes may be also used.

Alternatively, the backside sealing resin 504 may comprise the same resin material used for the surface side sealing resin 502.

In the present invention, it is possible to dispose a back face reinforcing member (not shown in the figure) outside the back face protective member 505 in order to improve the mechanical strength of the solar cell module and in order to prevent the solar cell module from being distorted or warped due to changes in the environmental temperature. The back face reinforcing member may comprise a steel plate, a plastic plate, or a fiber-glass reinforced plastic plate (or a so-called FRP plate).

In the following, description will be made of a process for the production of a solar cell module as a semiconductor device according to the present invention using the foregoing photovoltaic element, surface side sealing resin, surface protective member, backside sealing resin, and back face protective member.

In a typical embodiment, to enclose a light receiving face of the photovoltaic element 501 by the surface side sealing resin 502 and the surface protective member 503, a sheet of a given resin material usable as the surface side sealing resin is provided, the sheet is interposed between the photovoltaic element and the surface protective member, followed by subjecting to thermocompression bonding. The temperature and the period of time upon conducting the thermocompression bonding are properly determined so that crosslinking reaction sufficiently proceeds. To enclose the rear side of the photovoltaic element by the backside sealing resin 504 and the back face protective member 505 may be conducted in the same manner as in the above.

The thermocompression bonding may be conducted by means of a vacuum thermocompression bonding process. The vacuum thermocompression bonding process can include a thermocompression bonding process using a double vacuum chamber system and a thermocompression process using a single vacuum chamber system.

Herein, description will be made of an example of the thermocompression bonding process using a laminator of a single vacuum chamber system shown FIGs. 7(a) and 7(b) (hereinafter referred to as single vacuum chambered laminator).

The single vacuum chambered laminator shown in FIGs. 7(a) and 7(b) is substantially the same as the single vacuum chambered laminator shown in FIG. 3.

First, there is provided such a stacked body explained with reference FIG. 4. Particularly, as a stacked body 704 in FIGs. 7(a) and 7(b), there is provided a stacked body comprising a photovoltaic element 401, a surface protective member 404, a back face protective member 405, and a sealing resin 403. In a preferred embodiment, one or more of a nonwoven fiber member 402 such as a nonwoven glass fiber member or a nonwoven organic resin fiber member are inserted in the stacked body. In a more preferred embodiment, such nonwoven fiber member is interposed between the photovoltaic element 401 and the surface side sealing resin 403 and also between the photovoltaic element 401 and the backside sealing resin 403 as shown in FIG. 4. As the nonwoven fiber member 402 is immersed in EVA as the sealing resin, it serves to facilitate the release of the air present in the gaps of the stacked body in the foregoing vacuuming step and also to prevent the EVA from being flown to end portions of the stacked body when the EVA is fused in the foregoing heat treatment step. In addition, the nonwoven fiber member serves as a reinforcing member for the EVA. By this, in the case where the surface protective member comprises a film, the nonwoven fiber member functions to prevent a damage present at the film from influencing to the photovoltaic element.

Now, the stacked body 704 is positioned on the surface of a mounting table 701, and a silicone rubber sheet as a flexible member 702 is superposed over the stacked body on the mounting table 701 while hermetically sealing between the mounting table and the flexible member 702 by means of an O-ring 703. (see, FIG. 7(a))

Thereafter, in a first step, the inside of the space containing the stacked body 704 between the flexible member 703 and the mounting table is exhausted to a predetermined vacuum degree through openings of an exhaust system 705 connected to a vacuum pump (not shown) through a pipe provided with a valve 706 by operating the vacuum pump, whereby the flexible member 702 is sagged toward the mounting table 701 side to thereby compress the stacked body 704. (see, FIG. 7(b))

Then, in a second step, an electric heater (not shown) installed in the mounting table 701 is energized to heat the stacked body to a predetermined temperature at which the EVA as the sealing resin of the stacked body can be crosslinked, and the stacked body is maintained at this temperature until the crosslinking of the EVA is completed.

In a third step, the stacked body thus treated is cooled, and the stacked body is taken out from the laminater. By this, there is obtained a solar cell module.

The first and second steps, the space containing the stacked body is made to be of a vacuum degree of 5 Torr or less. In a preferred embodiment, it is made to be of a vacuum degree of 1 Torr or less. When the vacuum degree is exceeding 5 Torr, even if the period of time for the first step should be prolonged, residual air bubbles are liable to remain in the sealing resin after the compression lamination of the stacked body. The period of time for the first step is preferably in the range of from 5 to 40 minutes or more preferably in the range of from 10 to 30 minutes.

In the case where the period of time for the first step is less than 5 minutes, the exhaustion of the air present in the gaps of the stacked body is insufficient and in this case, if the vacuum degree should be made to be less than 5 Torr, residual air bubbles are liable to remain in the stacked body. Further, in the case where the period of time for the first step, it takes a long period of time to complete the lamination of the stacked body, resulting in a reduction in the productivity.

In the following, the present invention will be described in more detail with reference to examples which are not intended to restrict the scope of the present invention.

Example 1

1. Preparation of amorphous silicon (a-Si) photovoltaic element (solar cell):

A solar cell having the configuration shown in FIGs. 6(a) and 6(b) and which has a semiconductor active layer composed of an amorphous silicon (a-Si) material was prepared in the following manner.

That is, there was firstly provided a well-cleaned stainless steel plate as a substrate 601. On the substrate 601, there was formed a two-layered back reflecting layer 602 comprising a 500 nm thick Al film and a 500 nm thick ZnO film by means of the conventional sputtering process. Successively, on the back reflecting layer 602, there was formed a tandem type a-Si photoelectric conversion semiconductor layer 603 comprising a 15 nm thick n-type layer/a 400 nm thick i-type layer/a 10 nm thick p-type layer/a 10 nm thick n-type layer/a 80 nm thick i-type layer/a 10 nm thick p-type layer being deposited in the named order from the substrate side by means of the conventional plasma CVD process, wherein an n-type a-Si film as each n-type layer was formed from a mixture composed of SiH₄ gas, PH₃ gas and H₂ gas; an i-type a-Si film as each i-type layer was formed from a mixture composed of SiH₄ gas and H₂ gas; and a p-type uc-Si film as each p-type layer was formed from a mixture composed of SiH₄ gas, BF₃ gas and H₂ gas. Then, on the semiconductor active layer 603, there was formed a 70 nm thick In₂O₃ film as a transparent and conductive layer 604 by means of the conventional heat resistance evaporation process wherein an In-source was evaporated in an O₂ atmosphere. Successively, an Ag-paste was screen-printed on the transparent and conductive layer 604, followed by drying, to thereby form a grid electrode as a collecting electrode 605. As for the resultant, a copper tub as a negative side power outputting terminal 606b was fixed to the substrate 601 using a stainless solder 608, and a tin foil tape as a positive side power outputting terminal 606a was fixed to the collecting electrode 605 using an electrically conductive adhesive 607. Thus, there was prepared an a-Si solar cell. In this way, there were obtained a plurality of a-Si solar cells. These solar cells were integrated in series connection to obtain a cell block having an outer size of 300 mm x 1200 mm.

The above procedures were repeated to obtain a plurality of cell blocks.

2. Preparation of module:

Using each of the cell blocks obtained in the above 1, there were prepared a plurality of solar cell modules each comprising a stacked body of the configuration shown in FIG. 8 in the following manner.

First, there was prepared a stacked body 800 comprising an ETFE (tetrafluoroethylene-ethylene copolymer) film 803/an EVA sheet 802/a nonwoven glass fiber member 804/a cell block 801 (that is, the cell block obtained in the above)/a nonwoven glass fiber member 804/an EVA sheet 802/a nylon film 805/an EVA sheet 802/a galvalume steel member 806.

Particularly, on the light incident side of the cell block 801 obtained in the above, there were laminated a nonwoven glass fiber member 804 comprising a CRANE GLASS 230 (trademark name, produced by Crane Company), an EVA sheet 802 of 460 μm in thickness comprising a PHOTOCAP A9918 (trademark name, produced by Springborn Laboratories Company), and a nonstretched ETFE film 803 of 50 μm in thickness having a surface treated by way of corona discharging treatment (to be contacted with said EVA sheet 802) comprising a TEFZEL FILM (trademark name, produced by Du Pont Company) in the named order. On the rear side of the resultant, there were laminated a nonwoven glass fiber member 804 comprising a CRANE GLASS 230 (trademark name, produced by Crane Company), an EVA sheet 802 of 460 μm in thickness comprising a PHOTOCAP A9918 (trademark name, produced by Springborn Labora-

tories Company), a nylon film 805 of 63.5 μm in thickness comprising a DARTEK (trademark name, produced by Du Pont Company), an EVA sheet 802 of 460 μm in thickness comprising a PHOTOCAP A9918 (trademark name, produced by Springborn Laboratories Company), and a galvalume steel member 806 of 0.27 mm in thickness comprising a TIMACOLOR GL (trademark name, produced by Daido Kohan Kabushiki Kaisha) in the named order. By this, there was obtained a stacked body 800.

The EVA sheet (comprising the PHOTOCAP A9918) used in the above has been widely using as a sealing member for a solar cell. And it is comprised of a mixture composed of 100 parts by weight of an EVA (ethylene-vinyl acetate copolymer) resin (having an vinyl acetate content of 33 wt.%), 3.0 parts by weight of a crosslinking agent, 0.3 part by weight of an UV absorber, 0.1 part by weight of a photo stabilizer, 0.2 part by weight of an antioxidant, and 0.25 part by weight of a silane coupling agent.

The stacked body obtained in the above was treated as will be described below.

That is, the stacked body was placed in the single vacuum chambered laminater shown in FIG. 3, wherein the stacked body (which is indicated by reference numeral 306 in the figure) was positioned on the mounting table 301 such that the galvalume steel member 806 of the stacked body was contacted with the surface of the mounting table 301, and a silicone rubber sheet as the flexible member 302 was superposed over the ETFE film 803 of the stacked body on the mounting table 301 as shown in FIG. 3. Thereafter, the space containing the stacked body 306 therein enclosed by the mounting table 301 and the silicone rubber sheet 302 was evacuated to a predetermined vacuum by operating the vacuum pump (not shown in the figure) through the openings of the exhaust system 304, wherein the flexible sheet 302 (the silicone rubber sheet) was sagged to compress the stacked body 306. Thereafter, while continuing this evacuation procedures, the space was evacuated under reduced pressure condition with a vacuum degree of 5 Torr for 5 minutes to thereby vacuum the stacked body, and thereafter, under this reduced pressure condition with the vacuum degree of 5 Torr, the stacked body thus vacuum-treated was heated to and maintained at 150 $^{\circ}\text{C}$ for 30 minutes by means of the electric heater 303 whereby heat-fusing the EVA sheets of the stacked body 306 while crosslinking them. Thereafter, the electric heater 303 was switched off, air from a fan (not shown in the figure) was supplied to cool the stacked body to a temperature of about 40 $^{\circ}\text{C}$, and the evacuation procedures were terminated. The stacked body thus treated was taken out from the laminater. By this, there was obtained a solar cell module.

In the above, the power outputting terminals 606a and 606b were previously extended to the rear side of the solar cell so that they could be wired to the outside through wiring holes previously provided at the galvalume steel member of the stacked body after the completion of the lamination treatment.

In this way, there were obtained a plurality of solar cell modules.

In the following, the above step of vacuuming the stacked body will be referred to as first treatment step, and the above step of subjecting the vacuum-treated stacked body to heat treatment under the reduced pressure condition will be referred to as second treatment step.

Evaluation

Using the resultant solar cell modules, evaluation was conducted with respect to residual air bubble, endurance against changes in environmental temperature, and endurance against changes in environmental temperature and humidity.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Example 1.

The evaluation of each of the above evaluation items was conducted in the following manner.

(1) Evaluation of the residual air bubble:

The number of air bubble remained in the sealing material of the solar cell module was optically examined. The number of air bubble found in the sealing material is shown in Table 1.

(2) Evaluation of the endurance against changes in environmental temperature:

The solar cell module was subjected to alternate repetition of a cycle of exposing to an atmosphere with - 40 $^{\circ}\text{C}$ for an hour and a cycle of exposing to an atmosphere with 90 $^{\circ}\text{C}$ for an hour 50 times, and thereafter, its exterior appearance was observed. The observed result is shown in Table 1. The observed result shown by a mark \bigcirc in Table 1 indicates a case where no change was observed for the exterior appearance. As for a case with a change in the exterior appearance, comments are described in Table 1.

(3) Evaluation of the endurance against changes in environmental temperature and humidity:

The solar cell module was subjected to alternate repetition of a cycle of exposing to an atmosphere with - 40 °C for an hour and a cycle of exposing to an atmosphere with 80 °C/85 %RH for 4 hours 50 times, and thereafter, its exterior appearance was observed. The observed result is shown in Table 1. The observed result shown by a mark ○ in Table 1 indicates a case where no change was observed for the exterior appearance. As for a case with a change in the exterior appearance, comments are described in Table 1.

Example 2

The procedures of Example 1 were repeated, except that in the preparation of the stacked body, an increased number of a-Si solar cells were integrated in series connection to obtain a cell block having an outer size of 600 mm x 1200, and using this cell block, a stacked body having a greater size than that of the stacked body in Example 1 was obtained and that the 5 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 1 was changed to 10 minutes because the stacked body having such greater size was considered to have an increase in the gaps present therein and therefore to have a greater exhaustion resistance than that of the stacked body in Example 1, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Example 2.

Example 3

There were prepared a plurality of cell blocks each comprising a plurality of a-Si solar cells integrated in series connection in the same manner as in Example 1.

Using each of the cell blocks obtained in the above, there were prepared a plurality of solar cell modules each comprising a stacked body of the configuration shown in FIG. 9 in the following manner.

That is, there was prepared a stacked body 800 comprising a glass plate 903/a unwoven glass fiber member 804/an EVA sheet 802/a nonwoven glass fiber member 804/an EVA sheet 802/a nonwoven glass fiber member 804/a cell block 801 (that is, the cell block obtained in the above)/a nonwoven glass fiber member 804/an EVA sheet 802/an Tedlar film 905.

Particularly, on the light incident side of the cell block 801 obtained in the above, there were laminated a nonwoven glass fiber member 804 comprising a CRANE GLASS 230 (trademark name, produced by Crane Company), an EVA sheet 802 of 800 μm in thickness comprising a PHOTOCAP A9918 (trademark name, produced by Springborn Laboratories Company), a nonwoven glass fiber member 804 comprising a CRANE GLASS 230 (trademark name, produced by Crane Company), an EVA sheet 802 of 800 μm in thickness comprising a PHOTOCAP A9918 (trademark name, produced by Springborn Laboratories Company), a nonwoven glass fiber member 804 comprising a CRANE GLASS 230 (trademark name, produced by Crane Company), and a white tempered glass plate 903 of 3.2 mm in thickness comprising a SOLATEX (trademark name, produced by AFG company) in the named order. On the rear side of the resultant, there were laminated a nonwoven glass fiber member 804 comprising a CRANE GLASS 230 (trademark name, produced by Crane Company), an EVA sheet 802 of 800 μm in thickness comprising a PHOTOCAP A9918 (trademark name, produced by Springborn Laboratories Company), and a Tedlar film (an aluminum foil sandwiched with Tedlar (trademark name)) 905 (produced by Tohkaalumihaku Kabushiki Kaisha) in the named order. By this, there was obtained a stacked body 800.

The stacked body obtained in the above was treated as will be described below.

That is, the stacked body was placed in the single vacuum chambered laminater shown in FIG. 3, wherein the stacked body (which is indicated by reference numeral 306 in the figure) was positioned on the mounting table 301 such that the glass plate 903 of the stacked body was contacted with the surface of the mounting table 301, and a silicone rubber sheet as the flexible member 302 was superposed over the Tedlar film 905 of the stacked body on the mounting table 301 as shown in FIG. 3. Thereafter, the stacked body was treated by repeating the treating procedures in Example 1 using the laminater shown in FIG. 3.

By this, there was obtained a solar cell module.

In the above, the power outputting terminals 606a and 606b were previously extended to the rear side of the solar cell so that they could be wired to the outside through wiring holes previously provided at the tedlar film of the stacked body after the completion of the lamination treatment.

In this way, there were obtained a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees of in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Example 3.

Example 4

There were prepared a plurality of solar cell modules in the same manner as in Example 1, except that the stacked body was treated as will be described below.

That is, the stacked body was introduced into the double vacuum chambered laminater shown in FIG. 2, wherein the stacked body (which is indicated by reference numeral 209) was positioned on the mounting table 204 of the lower chamber 201 such that the galvalume steel member 806 of the stacked body was contacted with the surface of the mounting table 204 as shown in FIG. 2. Then, the inside of each of the upper chamber 202 and the lower chamber 201 was evacuated by operating the vacuum pump (not shown in the figure) at a vacuum degree of 5 Torr for 5 minutes, followed by energizing the electric heater 205 of the mounting table 204 to heat the stacked body to 100 °C. And the inside of the upper chamber 202 was returned to an atmospheric pressure while continuing the evacuation of the lower chamber 201 at the above vacuum degree of 5 Torr, wherein the flexible member 203 (comprising a silicone rubber sheet) was sagged to compress the stacked body, and the stacked body 209 was heated to and maintained at 150 °C for 30 minutes by means of the electric heater 205 under condition with a vacuum degree of 2 Torr whereby heat-fusing the EVA sheets of the stacked body 209 while crosslinking them. Thereafter, the electric heater was switched off, the stacked body was cooled to a temperature of about 40 °C by circulating a cooling water within the mounting table (this is not shown in the figure), and the evacuation procedures were terminated. The stacked body thus treated was taken out from the laminater. By this, there was obtained a solar cell module.

In this way, there were obtained a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Example 4.

Example 5

The procedures of Example 1 were repeated, except that in the preparation of the stacked body, no nonwoven glass fiber member was used and that the 5 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 1 was changed to 40 minutes for the reason that the nonwoven glass fiber member's exhaustion assisting effect for the gaps present in the stacked body could not be expected because of using no nonwoven glass fiber member, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Example 5.

Example 6

The procedures of Example 1 were repeated, except that that the 5 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 1 was changed to 50 minutes, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Example 6.

Comparative Example 1

The procedures of Example 1 were repeated, except that that the 5 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment

step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 1 was changed to 3 minutes, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 1.

Comparative Example 2

The procedures of Example 1 were repeated, except that that the vacuum degree of 5 Torr in not only the first treatment step (that is, the step of vacuuming the stacked body) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) but also the second treatment step in Example 1 was changed to 10 Torr, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 2.

Comparative Example 3

The procedures of Example 2 were repeated, except that that the 5 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 2 was changed to 3 minutes, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 3.

Comparative Example 4

The procedures of Example 3 were repeated, except that that the 5 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 3 was changed to 3 minutes, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 4.

Comparative Example 5

The procedures of Example 3 were repeated, except that that the vacuum degree of 5 Torr in not only the first treatment step (that is, the step of vacuuming the stacked body) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) but also the second treatment step in Example 3 was changed to 10 Torr, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 5.

Comparative Example 6

The procedures of Example 4 were repeated, except that the vacuum degree of the inside of each of the upper

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chamber 202 and lower chamber 201 until the pressure of the inside of the upper chamber 202 was returned to atmospheric pressure was made to be 15 Torr and that the vacuum degree of the inside of the lower chamber 201 after the pressure of the inside of the upper chamber 202 was returned to atmospheric pressure was made to be 10 Torr, to thereby obtain a solar cell module.

5 In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 6.

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Comparative Example 7

15 The procedures of Example 5 were repeated, except that that the 40 minutes duration of the first treatment step (that is, the step of vacuuming the stacked body at the vacuum degree of 5 Torr) prior to the start of the second treatment step (that is, the step of subjecting the vacuum-treated stacked body to the heat treatment) in Example 5 was changed to 3 minutes, to thereby obtain a solar cell module.

In this way, there were prepared a plurality of solar cell modules.

Using the resultant solar cell modules, evaluation was conducted in the same manner as in Example 1.

The evaluated results obtained are collectively shown in Table 1.

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In Table 1, there are also shown the vacuum degrees in the first and second treatment steps, the period of time during which the first treatment step was conducted, and the outer size of the cell block in Comparative Example 7.

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Table 1

	vacuum degree (Torr)		period of time for the first treatment step (min.)	outer size of cell block (mm×mm)	evaluation results		
	first treatment step (*1)	second treatment step (*2)			residual air bubble (number of air bubbles remained)	endurance against changes in environmental temperature	endurance against changes in environmental temperature and humidity
Example 1	5	5	5	300×1200	0	○	○
Example 2	5	5	10	600×1200	0	○	○
Example 3	5	5	5	300×1200	0	○	○
Example 4	5	2 (after the stacked body was compress-bonded)	5	300×1200	0	○	○
Example 5	5	5	40	300×1200	0	○	○
Example 6	5	5	50	300×1200	0	○	○
Comparative Example 1	5	5	3	300×1200	5~10	○	○
Comparative Example 2	10	10	5	300×1200	>100	the surface protective film peeled	the surface protective film peeled
Comparative Example 3	5	5	3	600×1200	10~20	○	○
Comparative Example 4	5	5	3	300×1200	5~10	○	○
Comparative Example 5	10	10	5	300×1200	>100	○	○
Comparative Example 6	15	10 (after the stacked body was compress-bonded)	5	300×1200	>100	the surface protective film peeled	the surface protective film peeled
Comparative Example 7	5	5	3	300×1200	>100	○	○

*1: the step of vacuuming the stacked body

*2: the step of subjecting the vacuum-treated stacked body to heat treatment

Based on the results shown in Table 1, the following facts are understood. That is, any of the solar cell modules obtained in the above examples is absolutely free of a residual air bubble and has an excellent exterior appearance.

And it is understood that any of the solar cell modules obtained in the above examples is satisfactory in the evaluation of each evaluation item of the endurance against changes in environmental temperature (the temperature cycle test) and the endurance against changes in environmental temperature and humidity (the temperature and humidity cycle test).

On the other hand, it is understood that any of the solar cell modules obtained in the above comparative examples wherein the vacuum degree in the first treatment step (that is, the step of vacuuming the stacked body) and the second

treatment step (that is, the step of subjecting the vacuum-treated stacked body to heat treatment) was made to be beyond 5 Torr has a number of residual air bubbles therein.

Further, in the case where the duration of the first treatment step (that is, the step of vacuuming the stacked body) is less than 5 minutes, it is understood that microdelaminations of several millimeters in diameter are occurred at the interface between the film and the sealing material in the temperature cycle test and the temperature and humidity cycle test.

In the case of the above Example 6 wherein the duration of the first treatment step (that is, the step of vacuuming the stacked body) was made to be 50 minutes, it is understood that the solar cell module obtained is not problematic in terms of residual air bubble and reliability. But it seems that the solar cell production process of Example 6 is not always satisfactory in terms of productivity.

Now, it is necessary for a solar cell module to have no air bubble therein and to have an excellent exterior appearance in order to secure its long use reliability in outdoors. It can be said that any of the solar cell modules obtained in the above examples meets these conditions.

As apparent from the above results, according to the present invention, there are provided such various advantages as will be described below.

(1) By subjecting a stacked body as a solar cell module to vacuum compression treatment, the stacked body becomes to be free of a residual air bubble therein. Particularly, by sufficiently vacuuming the stacked body, the air present in the gaps of the stacked body is sufficiently released to the outside to prevent the stacked body from suffering the generation of an air bubble therein.

(2) It is possible to produce a semiconductor device such as a solar cell module which is free of the generation of a separation between the surface material and the sealing resin in reliability tests such as temperature cycle test, temperature and humidity cycle test, and the like. Particularly, as the vacuum degree of the space containing a stacked body as the semiconductor device therein is made to be 5 Torr or less, when the sealing resin of the stacked body is crosslinked by means of an organic peroxide, the occurrence of a covalent bonding between the surface material and the sealing resin and the crosslinking of the sealing resin itself are not hindered by oxygen. By this, an improvement in the adhesion between the surface material and the sealing resin is attained to result in making the semiconductor device to have an improved reliability.

(3) By inserting a nonwoven glass fiber member or/and a nonwoven organic resin fiber member in a stacked body as a semiconductor device such as a solar cell, there can be attained a markedly improved vacuum compression treatment effect for the stacked body. That is, these nonwoven fiber members disposed in the stacked body assist the release of the air present in the stacked body in the vacuum compression treatment, and because of this, the stacked body having subjected to the vacuum compression treatment becomes such that is substantially zero in the number of an air bubble remained therein.

(4) By using EVA (ethylene-vinyl acetate copolymer) at least as the sealing resin between the semiconductor element (or the photovoltaic element) and the surface material, those effect previously described are provided without greatly changing the constitution of the conventional covering material.

(5) By crosslinking EVA used as the sealing resin with an organic peroxide, the sealing resin becomes to have an improved heat resistance. That is, there are not entailed problems such that the sealing resin is softened under use condition with a high temperature to cause a separation at the surface material and the softened sealing resin is flown to the outside. In addition, the crosslinking of the sealing resin is not hindered by oxygen, and because of this, the reliability of the semiconductor device (the solar cell module) is markedly improved for the reasons described in the above (2).

(6) By employing the foregoing single vacuum chamber system of supporting a stacked body as a semiconductor device such as a solar cell module between the mounting table and the flexible member (comprising a silicone rubber member) and vacuuming the space between the mounting table and the flexible member to compress the stacked body by the flexible member, there are provided advantages such that the structure of the laminater used upon the lamination in the production of a semiconductor device such as a solar cell module can be simplified and the apparatus cost can be desirably reduced. This situation makes it unnecessary to have a large facility investment for the mass-production of a semiconductor device such as a solar cell module. Further, various laminaters can be optionally used. In addition, the advantages of the present invention when said single vacuum chamber system is employed are significant. That is, in the case of the conventional single chamber system, when the compression treatment of a stacked body as a semiconductor device such as a solar cell module is conducted at the same time when the stacked body is vacuumed, there entail problems in that the gaps in the stacked body become markedly narrower in comparison with the case of using the conventional double vacuum chamber system and therefore, the stacked body becomes such that has a large exhaustion resistance, and because of this, residual air bubbles are very likely to occur after the vacuum compression treatment. However, the present invention markedly improves this situation.

(7) By using a fluorine-containing polymer film as the transparent surface material, there can be attained a surface

covering material having an excellent weatherability for a semiconductor device such as a solar cell module. Particularly, the use of the sealing resin and the fluorine-containing polymer in combination provides an excellent weatherability.

(8) By using a film composed of ETFE (ethylene-tetrafluoroethylene copolymer) as the fluorine-containing polymer film, there can be attained a surface covering material excelling in weatherability, transparency, and physical strength for a semiconductor device such as a solar cell module.

(9) By making the fluorine-containing polymer film to have a corona-discharged surface to be contacted with the sealing resin, there can be attained an improvement in the adhesion between the sealing resin and the fluorine-containing polymer film.

Now, it is a matter of course to say that the process of producing a semiconductor device such as a solar cell module in the present invention is not limited to the above examples. These examples may be optionally modified within the range of hindering the principle of the present invention. The semiconductor element used in the present invention can include, besides photovoltaic elements, other photoelectric conversion elements such as photodetectors and light emitting elements.

Incidentally, as apparent from the above description, the process of producing a semiconductor device including a solar cell module in the present invention comprises the steps of providing a stacked body comprising a semiconductor element (such as a photovoltaic element or the like) and a sealing resin which are interposed between a surface protective member and a back face protective member, vacuuming said stacked body at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting said stacked body thus vacuum-treated to thermocompression bonding under condition with a vacuum degree of 5 Torr or less, and cooling said stacked body having subjected to said thermocompression bonding to engage in contact bonding. According to this process, the stacked body is sufficiently vacuumed to release the air present in the gaps of the stacked body, whereby the stacked body is effectively prevented from the occurrence of an air bubble therein. And, in the case where the sealing resin is crosslinked by means of an organic peroxide, the occurrence of a covalent bonding between the surface protective member and the sealing resin and the crosslinking of the sealing resin itself are not hindered by oxygen. Therefore, there can be attained an excellent adhesion between the surface protective member and the sealing resin. In addition, even under use condition with a high temperature, the sealing resin is hardly softened and therefore, a separation is hardly occurred at the interface between the surface protective member and the sealing resin. Hence, the semiconductor device is highly reliable.

A semiconductor device having a semiconductor element, characterized in that said semiconductor device comprises a stacked body obtained by providing a laminate comprising said semiconductor element and a sealing resin which are interposed between a surface member and a back face member, vacuuming said laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting the laminate thus treated to thermocompression bonding at a vacuum degree of 5 Torr or less, and cooling the laminate having subjected to said thermocompression bonding to engage in contact bonding. And a process for the production of a semiconductor device. The semiconductor device is free of the generation of air bubble therein.

Claims

1. A semiconductor device having a semiconductor element, characterized in that said semiconductor device comprises a stacked body obtained by providing a laminate comprising said semiconductor element and a sealing resin which are interposed between a surface member and a back face member, vacuuming said laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting the laminate thus treated to thermocompression bonding at a vacuum degree of 5 Torr or less, and cooling the laminate having subjected to said thermocompression bonding to engage in contact bonding.
2. A semiconductor device according to claim 1, wherein the stacked body has a nonwoven glass fiber, a nonwoven organic resin fiber, or both of these fibers inserted therein.
3. A semiconductor device according to claim 1, wherein the sealing resin is positioned between the semiconductor element and the surface member, and the sealing resin comprises ethylene-vinyl acetate copolymer.
4. A semiconductor device according to claim 1, wherein the surface member comprises a transparent film composed of a fluorine-containing polymer.
5. A semiconductor device according to claim 3, wherein the ethylene-vinyl acetate copolymer is crosslinked by an organic peroxide.
6. A semiconductor device according to claim 4, wherein the fluorine-containing polymer is ethylene-tetrafluoroethyl-

ene copolymer.

7. A semiconductor device according to claim 4, wherein the transparent fluorine-containing polymer film has a corona-discharged surface contacted with the sealing resin.
8. A semiconductor device according to claim 1, wherein the semiconductor element is a photoelectric conversion element.
9. A semiconductor device according to claim 1, wherein the semiconductor element is a photovoltaic element.
10. A semiconductor device according to claim 1, wherein the semiconductor element is a photodetector or a light emitting element.
11. A semiconductor device according to claim 1 which is a solar cell module.
12. A process for producing a semiconductor device by subjecting a laminate comprising a semiconductor element and a sealing resin which are interposed between a surface member and a back face member to thermocompression bonding under reduced condition, characterized in that said process comprises the steps of:
 - (a) vacuuming said laminate,
 - (b) subjecting the vacuum-treated laminate to thermocompression bonding at a vacuum degree of 5 Torr or less, and
 - (c) during said step (b), cooling the laminate having been subjected to thermocompression bonding to engage in contact.
13. The process according to claim 12, wherein the thermocompression bonding of the laminate includes steps of supporting the laminate between a mounting table and a flexible member, and vacuuming a space between said mounting table and said flexible member to compress the laminate.
14. The process according to claim 12, wherein the laminate has a nonwoven glass fiber, a nonwoven organic resin fiber, or both of these fibers inserted therein.
15. The process according to claim 12, wherein the sealing resin is positioned between the semiconductor element and the surface member, and the sealing resin comprises ethylene-vinyl acetate copolymer.
16. The process according to claim 15, wherein the ethylene-vinyl acetate copolymer is crosslinked by an organic peroxide.
17. The process according to claim 12, wherein the surface member comprises a transparent film composed of a fluorine-containing polymer.
18. The process according to claim 17, wherein the fluorine-containing polymer is ethylene-tetrafluoroethylene copolymer.
19. The process according to claim 17, wherein the transparent fluorine-containing polymer film has a corona-discharged surface contacted with the sealing resin.
20. The process according to claim 13, wherein the flexible member is a flexible sheet.
21. The process according to claim 20, wherein the flexible sheet is a silicone rubber sheet.
22. The process according to claim 12, wherein the thermocompression bonding of the laminate is conducted by utilizing a flexible sheet which is larger than the laminate.
23. The process according to claim 13, wherein the vacuuming is conducted only between the mounting table and the flexible member.
24. The process according to claim 13, wherein the vacuuming is conducted only for the space provided by the flexible member on the mounting table side.

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25. The process according to claim 13, wherein the vacuuming is conducted on the both sides of the flexible member, and the thermocompression bonding of the laminate includes a step of heightening the pressure on the side of the flexible which is opposite to the mounting table.

5 26. The process according to claim 12, wherein the semiconductor element is a photoelectric conversion element.

27. The process according to claim 12, wherein the semiconductor element is a photovoltaic element.

10 28. The process according to claim 12, wherein the semiconductor element is a photodetector or a light emitting element.

29. The process according to claim 12, wherein the semiconductor device is a solar cell module.

15 30. The process according to claim 12, wherein the vacuuming treatment in the step (a) is conducted for 5 to 40 minutes.

31. The process according to claim 12 which includes a step of vacuuming the laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes after the vacuuming treatment of the step (a).

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FIG. 1

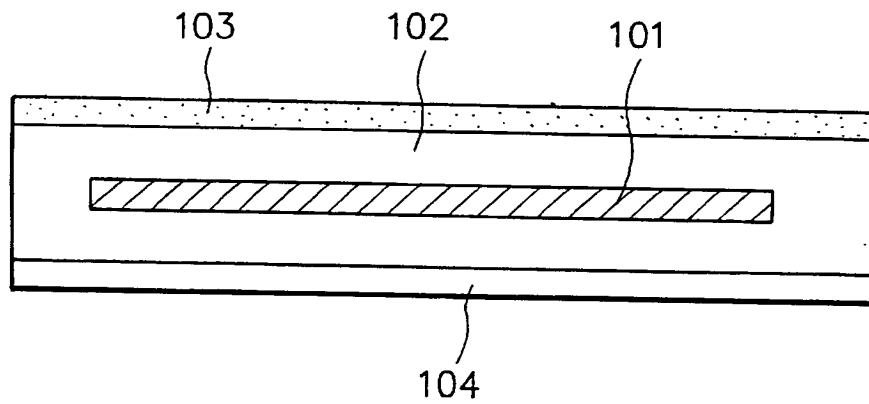


FIG. 2

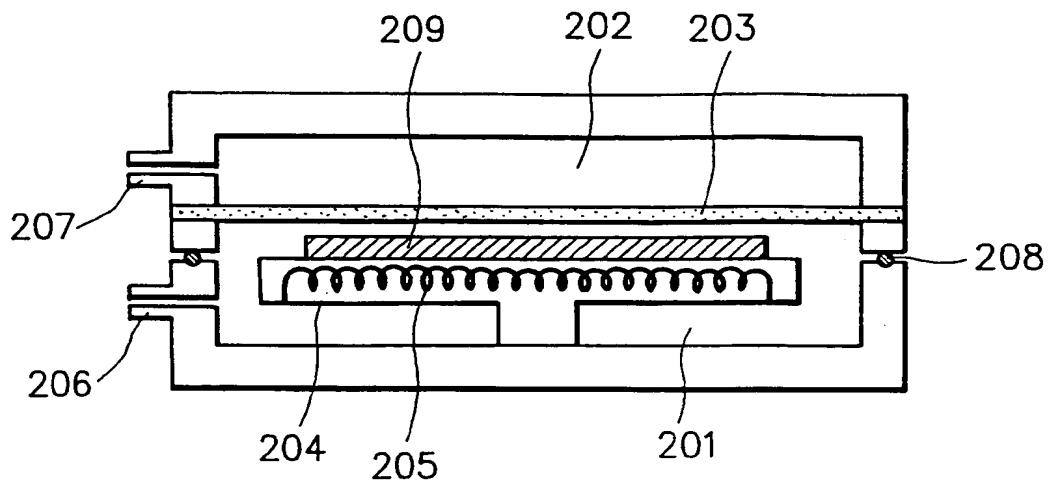


FIG. 3

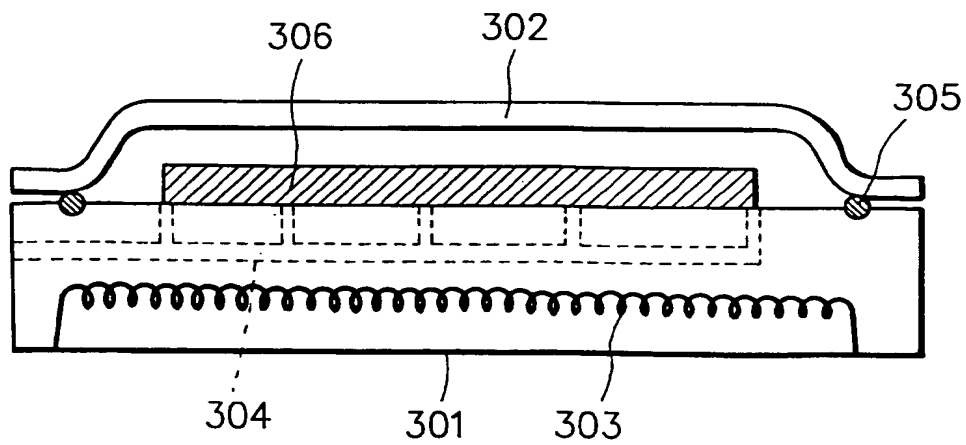


FIG. 4

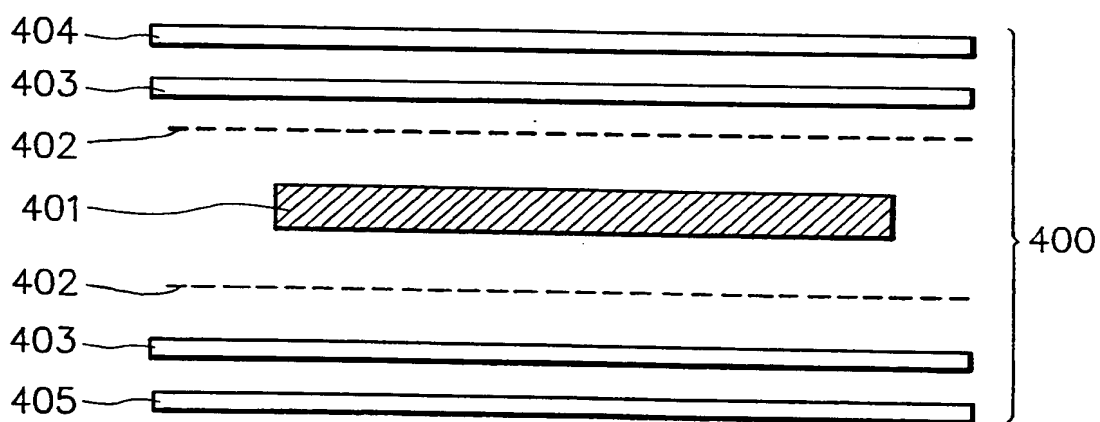


FIG. 5

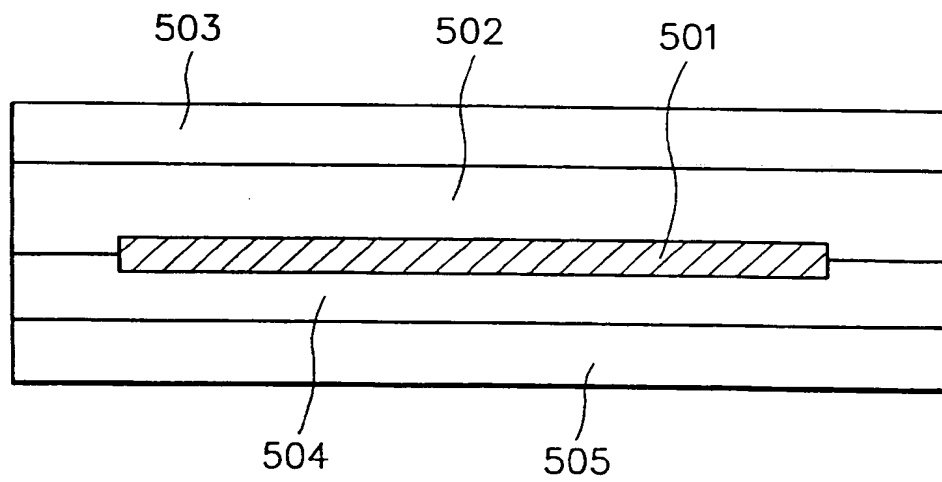


FIG. 6(a)

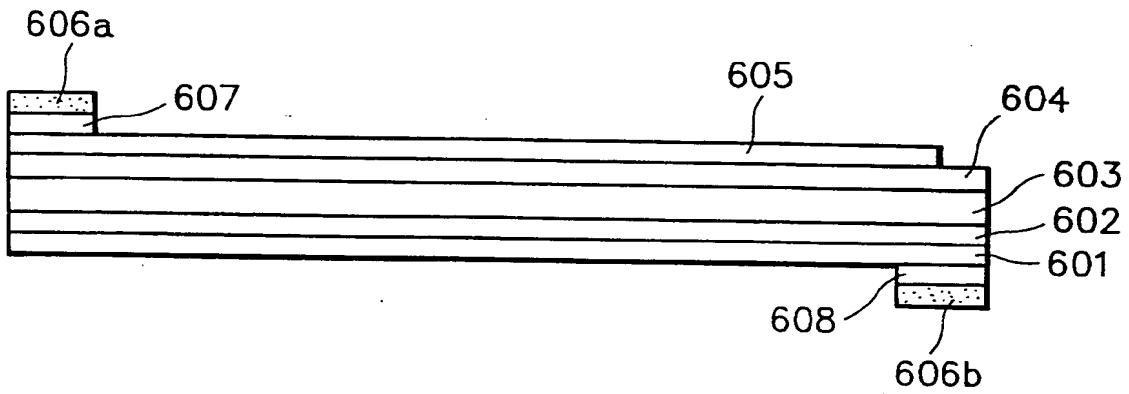


FIG. 6(b)

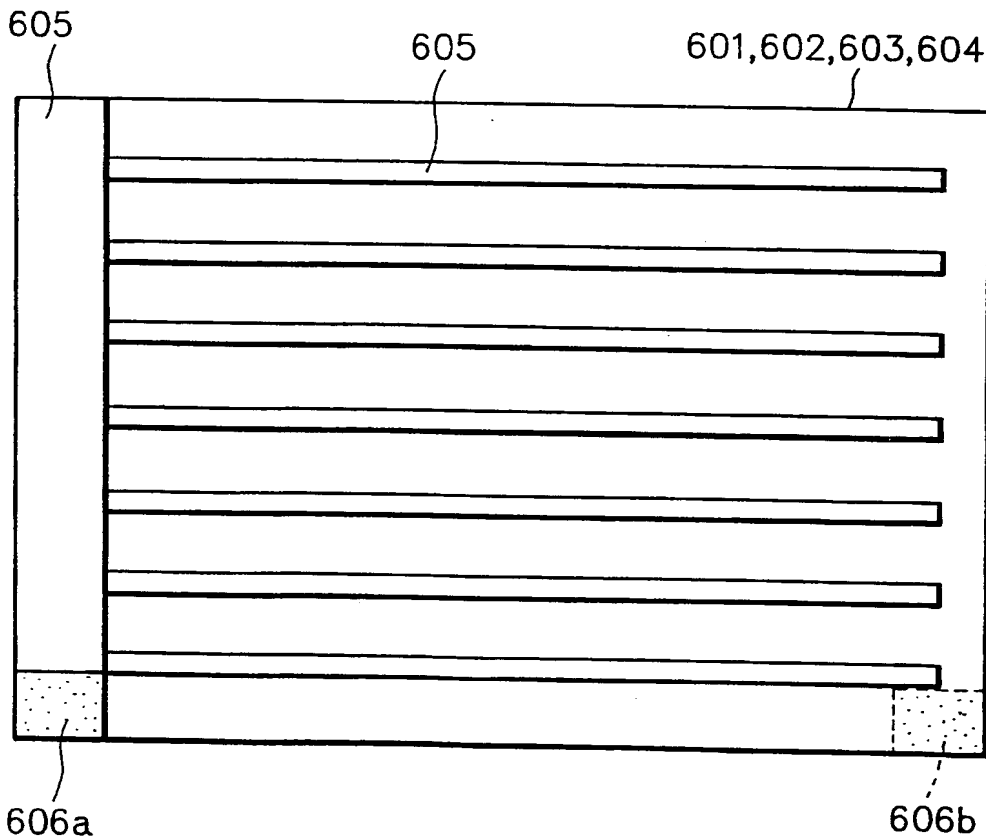


FIG. 7(a)

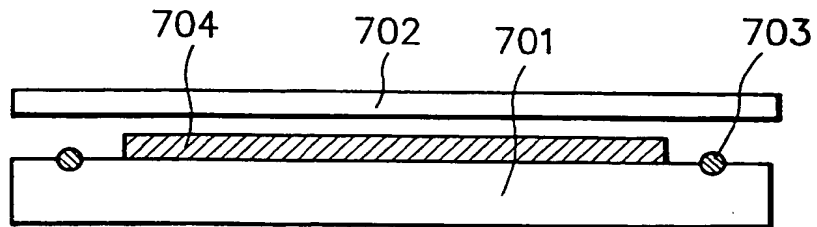


FIG. 7(b)

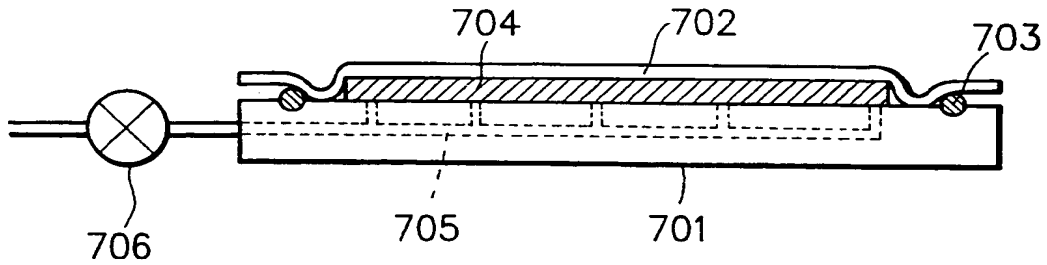


FIG. 8

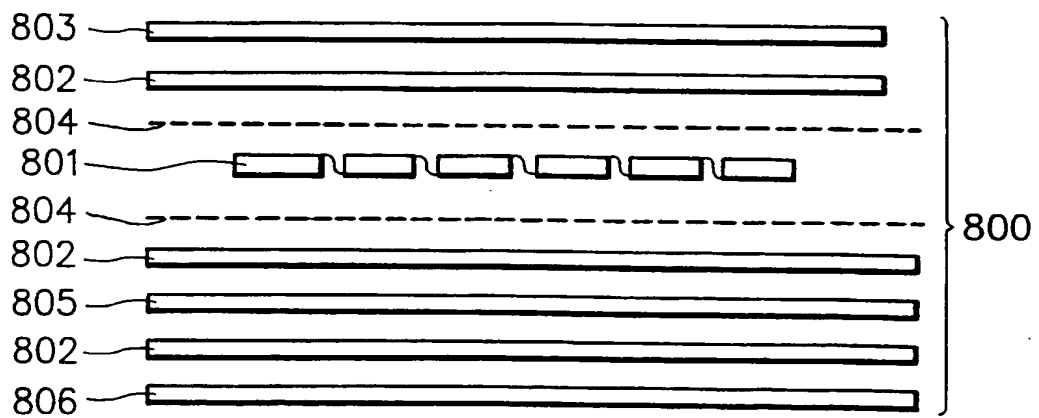
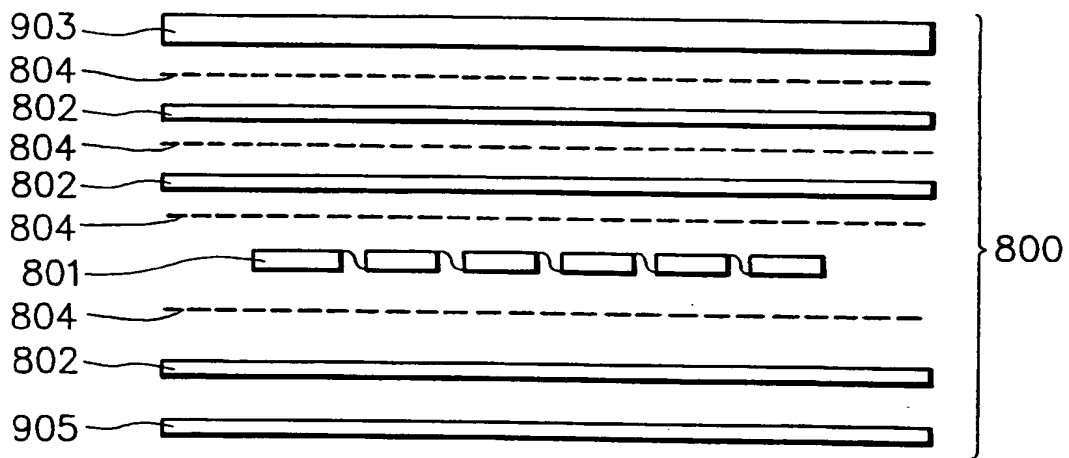
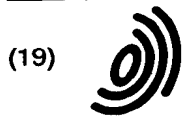


FIG. 9





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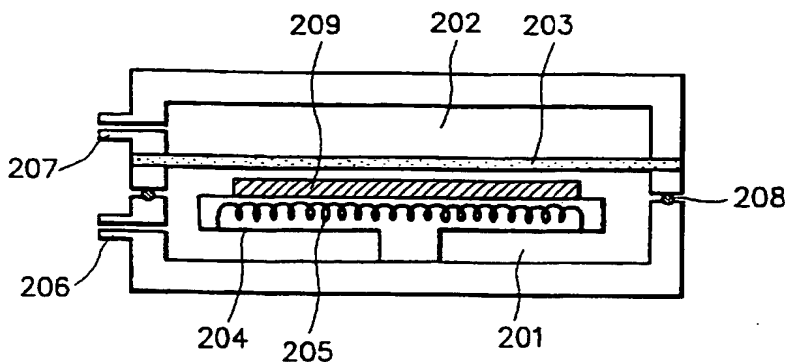
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(54) A semiconductor device and a process for the production thereof

(57) A semiconductor device having a semiconductor element, characterized in that said semiconductor device comprises a stacked body obtained by providing a laminate comprising said semiconductor element and a sealing resin which are interposed between a surface member and a back face member, vacuuming said laminate at a vacuum degree of 5 Torr or less for 5 to 40 minutes, subjecting the laminate thus treated to thermo-

compression bonding at a vacuum degree of 5 Torr or less, and cooling the laminate having subjected to said thermocompression bonding to engage in contact bonding. And a process for the production of a semiconductor device. The semiconductor device is free of the generation of air bubble therein.

FIG. 2



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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 658 943 A (CANON KK) 21 June 1995 * page 5, line 39 - page 7, line 46 * * page 13, line 8 - line 15 *	1,3-9,11	H01L31/048
X	WO 94 29106 A (ISOVOLTA ; FALK JOHANN (AT); PLESSING ALBERT K (AT)) 22 December 1994 * the whole document *	12,13, 15,17, 20-27,29	
X	EP 0 528 566 A (MORTON INT INC) 24 February 1993 * column 11, line 35 - column 12, line 52; figures 13-17 *	12,13, 20-25	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H01L
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 May 1999	Examiner Acco, S
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 96 11 1710

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25-05-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0658943 A	21-06-1995	JP 7022637 A	24-01-1995
		US 5578141 A	26-11-1996
		WO 9501655 A	12-01-1995
		US 5718772 A	17-02-1998
WO 9429106 A	22-12-1994	AT 175625 T	15-01-1999
		AU 676330 B	06-03-1997
		AU 6836994 A	03-01-1995
		CA 2141946 A	22-12-1994
		DE 59407644 D	25-02-1999
		EP 0655976 A	07-06-1995
		ES 2126115 T	16-03-1999
		JP 8500214 T	09-01-1996
		US 5593532 A	14-01-1997
EP 0528566 A	24-02-1993	IT 1250461 B	07-04-1995
		AT 160109 T	15-11-1997
		CA 2075526 A	10-02-1993
		DE 69223101 D	18-12-1997
		DE 69223101 T	05-03-1998
		ES 2111050 T	01-03-1998
		HK 1002932 A	25-09-1998
		JP 1931246 C	12-05-1995
		JP 5200880 A	10-08-1993
		JP 6055444 B	27-07-1994
		MX 9204595 A	01-02-1993
		SG 46379 A	20-02-1998
		US 5292388 A	08-03-1994

EPO FORM P0459

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